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Electronic Warfare Closed Loop Laboratory (EWCLL) Antenna Motor Software and Hardware Development

by Neal Tesny

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14. ABSTRACT

Software and hardware were developed to control the rotation of the 6 double-ridged waveguide horn antennas that are used in the Electronic Warfare Closed Loop Laboratory (EWCLL) test chamber. The software and hardware are described and a "user's guide" is provided. The software is written in LabVIEW.

15. SUBJECT TERMS

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1. Introduction

Software and hardware were developed to control the rotation of the 6 double-ridged waveguide horn antennas that are used in the Electronic Warfare Closed Loop Laboratory (EWCLL) test chamber. The software is written in LabVIEW. This report describes the EWCLL antenna motor software and hardware that control the stepper motors that rotate the 6 horn antennas in the US Army Research Laboratory's closed loop (CL) chamber.

2. Quick-Start Guide

The following is given as a guide to let a user start using the software as rapidly as possible. For more detailed information about the software and hardware, see the appropriate sections.

2.1 Starting the Program

To start the program, start the LabVIEW shell program. Then open and run the program "zDashboard6motorsV1b.vi". (A list of software virtual instrument [vi] programs are provided in Appendix A.) This starts the main dashboard of the software. The location of the software is given in Appendix B.

2.2 Zeroing Routine

When the motors or software are first powered up, each motor is labeled as being not zeroed by the light and text message "Motor angle not verified." The antennas should not be used in this state, because it signifies the motor angles may be off from the angle displayed for each antenna. The user must zero all of the motor angles to ensure the motor angles are verified.

The motors can be zeroed either individually or all at once. To zero an individual motor, first navigate to the panel labeled "Normal operation" by pressing the corresponding tab on the dashboard. Then press the button labeled "verify motor position" that corresponds to the number of the motor of interest. Alternatively, the motors can also be zeroed by pressing the button labeled "Zero all". This will zero all the motors sequentially starting with Motor 1.

The motor specifications are provided in Appendix C.

2.3 Rotating Antennas

To rotate an antenna, first navigate to the panel labeled “Normal operation”. Then enter the desired angle in the box labeled “Desired angle” for the antenna to be rotated. Then press the button labeled “Go”. This causes the antenna to rotate to the desired angle and update the angle in the box labeled “Current angle”.

3. Software Description

The dashboard is divided into 4 panels, which are accessed by the tabs. These panels are as follows:

1) Normal operation. This panel is used for normal functions such as rotating the antennas and zeroing the motors.
2) Zero Setup
3) Advanced Setup
4) Status

These panels are shown in Figs. 1 through 4.

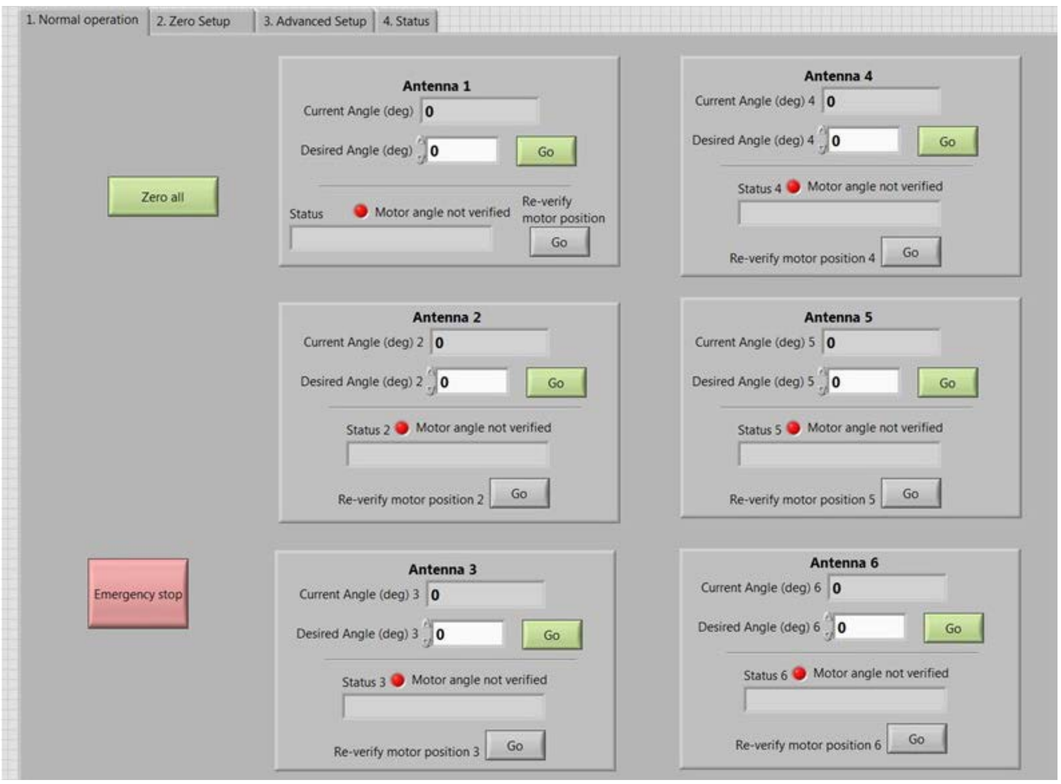

Fig. 1 Normal operation panel

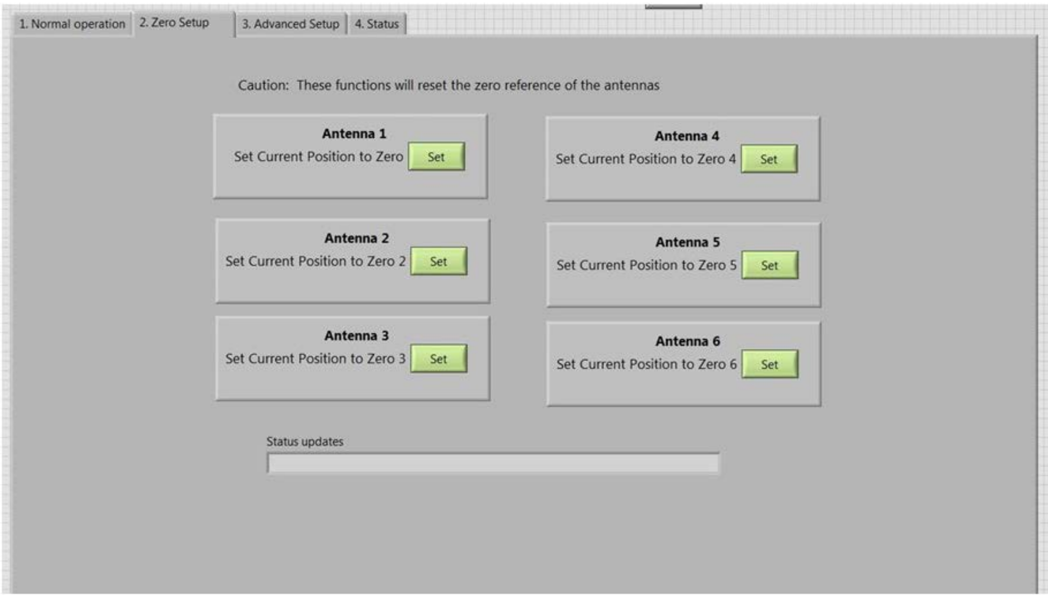

Fig. 2 Zero Setup panel

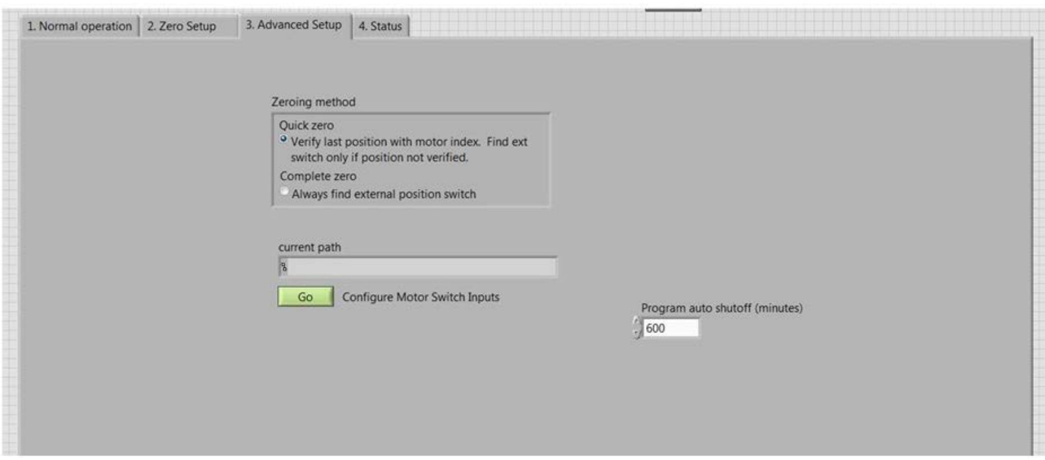

Fig. 3 Advanced Setup panel

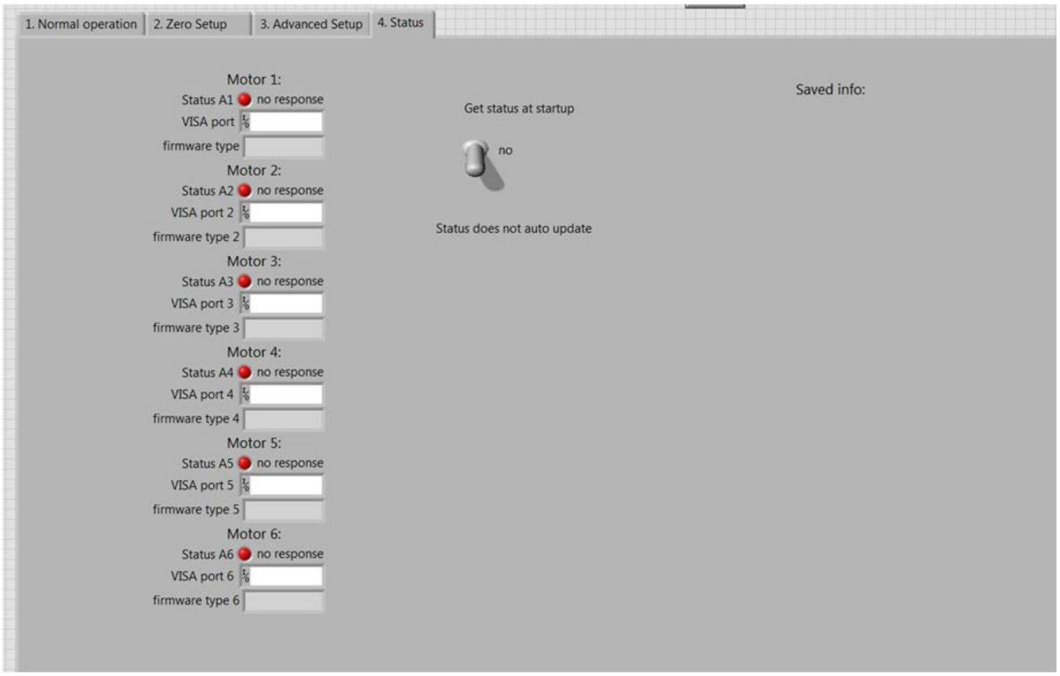

Fig. 4 Status panel

3.1 Start of the Day Calibration

The software will perform zeroing of the motors. This sets all of the motor angles to an angle of absolute zero. This zero reference can be adjusted if needed.

This step performs zeroing by using 2 absolute references: one inside the motor itself and the other by means of an external contact switch mounted on the motor axle.

3.2 Normal Operations Tab

3.2.1 Rotating Antennas

To rotate an antenna, enter the desired angle in the box labeled "Desired angle" for the antenna to be rotated. Then press the button labeled "Go". This causes the antenna to rotate to the desired angle and updates the angle in the box labeled "Current angle".

The antenna angle is stored whenever the antenna is rotated using the rotate functions on the "Normal Operations" front panel. This stored setting is used in verifying the antenna angle whenever a zeroing operation is performed. The software compares the current antenna angle with the stored angle during the zeroing operation.

3.2.2 Zeroing the Motors or Verifying the Motor Angles

When the motors or software are first powered up, each motor is labeled as being not zeroed by the light and text message "Motor angle not verified." The antennas should not be used in this state, because it signifies the motor angles may be off from the angle displayed for each antenna. The user must zero all of the motor angles to ensure the motor angles are verified.

The motors can be zeroed either individually or all at once. To zero an individual motor, first navigate to the panel labeled "Normal operation" by pressing the corresponding tab on the dashboard. Then press the button labeled "verify motor position" that corresponds to the number of the motor of interest. Alternatively, the motors can also be zeroed by pressing the button labeled "Zero all". This zeroes all of the motors sequentially starting with Motor 1.

The zeroing routine will correct for any changes in the antenna angles that may have occurred since the time of the last zeroing routine. This includes any minute changes such as a few hundredths of a degree or large changes such as someone intentionally turning the motor shaft to a different angle.

3.2.3 Emergency Stop

Pressing this button on the front panel sends a hard stop command to all of the motors causing them to immediately stop motion. A software restart will likely be needed after this, because this action interrupts all other motion commands.

3.3 Zero Setup Tab

Position the antenna to the desired angle that is to be set to the origin (0°), using the rotation functions on the "Normal operation" panel.

Click on the tab labeled "Zero Setup" to select the Zero Setup panel.

For the desired antenna, press the corresponding button labeled "Set" to reset the origin of the antenna.

The software will verify the angle by turning the motor to find the external switch and then will return the antenna to the zero angle.

Information related to the zeroed angle will be stored in a saved file. This information includes angle from external switch, angle from internal motor index, and time of last zero. The entire history of saved zero set data is saved, in case an accidental resetting of the zero position occurs and earlier zero data are desired.

3.4 Status Tab

This gives the connection status of the motors when the toggle switch is set to "Yes". It is used primarily for troubleshooting and setup.

Keeping the toggle switch set to the "off" position will save time during startup.

3.5 Advanced Setup Functions Tab

3.5.1 Zeroing Method

This lets the user select what method to use for verifying the position of the motors (i.e., zeroing them). The 2 choices for this option are the following:

1) Quick zero—Verifies the last position with the motor index. Find the external switch only if the position is not verified. This choice lets the software verify the motor angle by comparing it to the motor index. It does this by first rotating to find the index if it is not already detected, and then comparing it to the current angle and the last stored angle. If they are in agreement, then the motor angle is verified. If there is any discrepancy, then the software proceeds to locate the external switch and turn the motor to the last saved angle. This will correct for any incidental shifts in motor angle that may have occurred since the last zeroing routine. This option saves time during the zeroing process and is probably good enough for zeroing. Since there are 4,000 encoder steps in each motor, the odds of there being a gross error in the angle of the antenna is 1 in 4,000, and that is only if the antenna shaft was inadvertently rotated an exact angle of 36.00°!

2) Complete zero—Always find the external position switch. This option forces the software to always find the external switch during the zeroing process. This option adds more time to the zeroing process, especially the time to zero all 6 motors simultaneously.

The antenna angle is stored whenever the antenna is rotated using the rotate functions on the "Normal Operations" front panel.

3.5.2 Other Settings

On this panel, the current path shows where the stored files are located on the controller's file system.

Program auto-shutoff can also be set here. The program typically runs continuously, waiting for a button to be pressed or until directly stopped by the user. This setting

will stop the program after a set time. The default value is 600 min, which will stop it at the end of the day if it is still running.

4. Hardware Setup

4.1 Motor Accuracy

The motors have 4,000 steps per revolution, which makes them accurate to an angle of 0.09° with no gear transmission. However, all of the CL motors have a gearbox with a 10:1 gear ratio. This makes the antenna positioning accurate to an angle of 0.009°.

4.2 Numbering of the Motors

The motors are numbered 1 through 6. Motors 1 through 3 are located on the "Source" side of the CL chamber, and motors 4 through 6 are on the "Receive" side. They are numbered starting with the topmost antenna running counterclockwise when viewing them from the back of the motors. With this numbering, opposite motor pairs are as follows: motors 1 and 4 are the topmost motors; motors 2 and 6 are opposite each other; and motors 3 and 5 are opposite each other. Three of the motors mounted on the CL chamber are shown in Fig. 5.

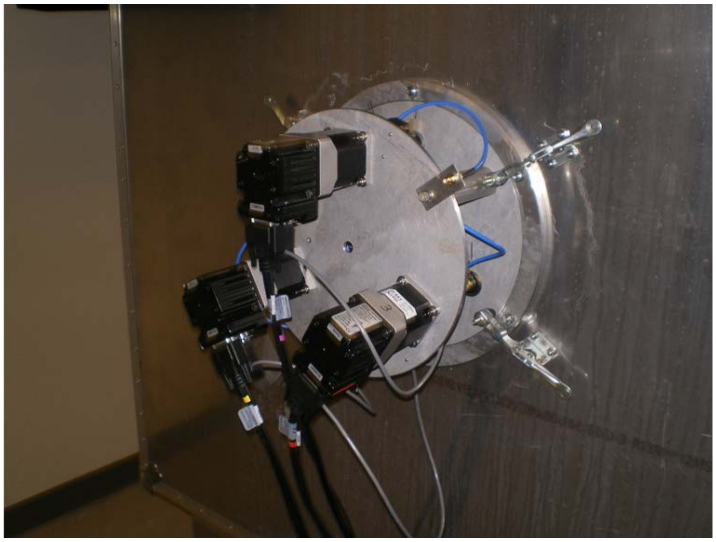

Fig. 5 Antenna positioning motors mounted on CL test cell

4.3 Angle and Alignment of the Motors

A positive angle will produce a counterclockwise turn viewing the antenna from the back of the motor. This rule applies to all of the antennas. Hence to rotate

antennas on opposite sides of the cell so that they are coaligned, the user must enter opposite angles for antennas on each side of the cell.

For example, if motor 1 is rotated +30°, to align motor 4 to it, the user would rotate it to an angle of –30°.

4.4 Motor Power

The motors are powered from a single power supply that has 6 output feeds on it. The motors will operate on voltages from 20 to 48 V. Since we are running them at very slow speeds with essentially no load, a voltage at the lower end of this range is adequate.

4.5 Motor Interfaces

The motors are connected via RS232 (aka "serial" format) cables. These are interfaced through the PCI Extension for Instrumentation (PXi) chassis, which is connected to the PC controller. A standalone PXI controller can also be used to run the motor control software. The power supply and PXI chassis are shown in Fig. 6. A block diagram of the motor connections is shown in Fig. 7. Figure 8 shows the front panel of the vi cllMotorBasic.

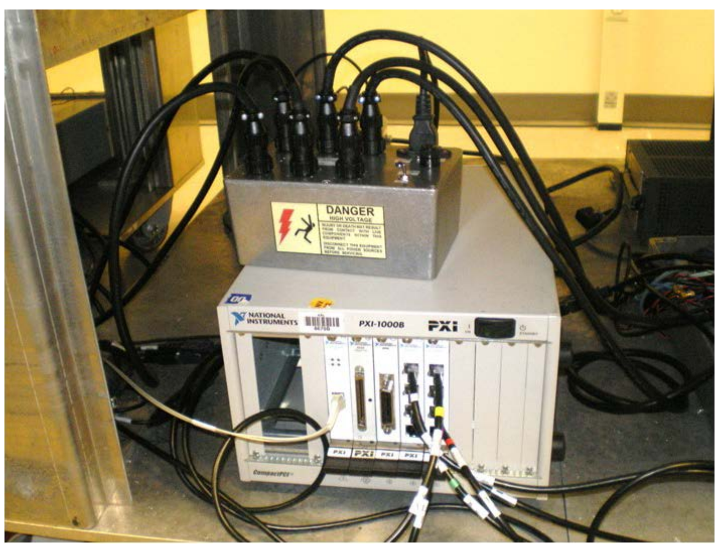

Fig. 6 Power supply with 6 feeds, on top of PXi chassis with 6 serial port output

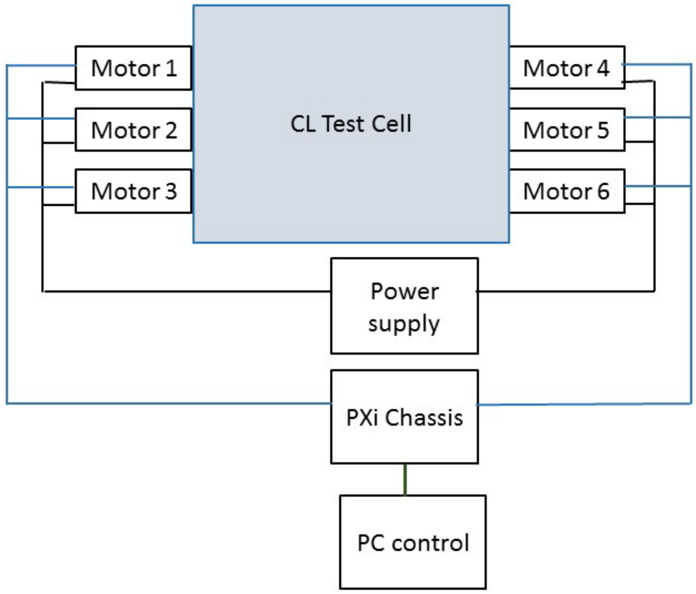

Fig. 7 Block diagram of motor connections

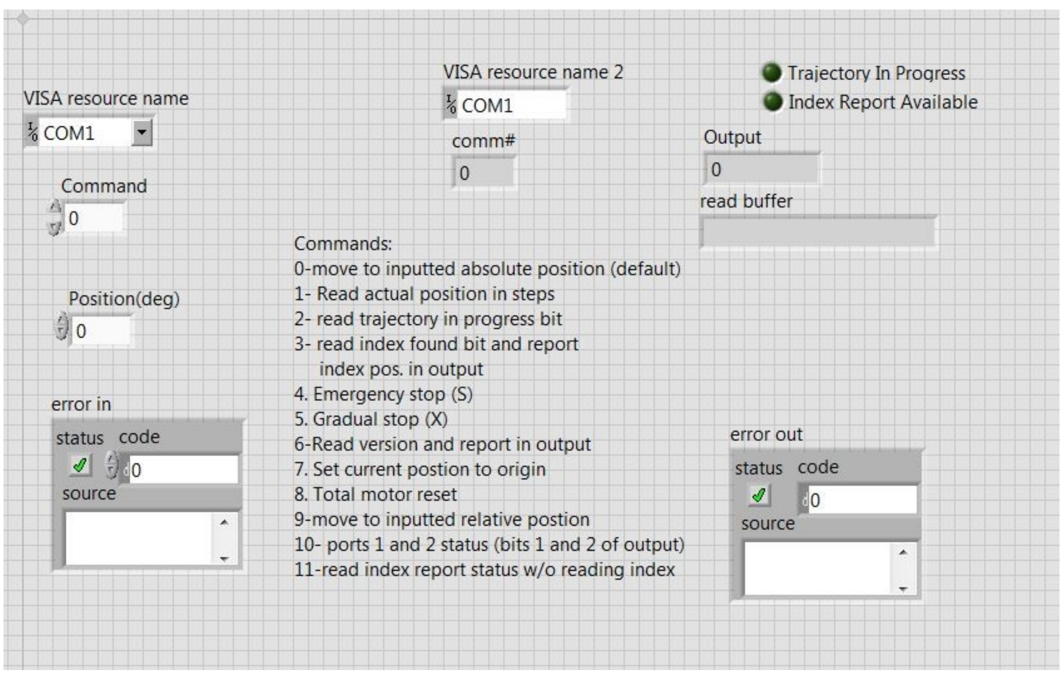

Fig. 8 The front panel of the vi cllMotorBasic

5. Conclusion

Precision control of the 6 wideband horn antennas in the EWCLL test chamber has been implemented. To achieve this, a software suite has been developed to provide precision control and zeroing necessary for EWCLL operations. The hardware configuration and software suite have been described. A quick-start guide has also been given.

Appendix A. Software Modules

A-1 Listing of Modules Used

A list of virtual instrument (vi) programs that the software uses to perform its functions is given below. A short description of major modules follows.

zDashboard6motorsV1b.vi
cllMotorMoveClassFour1b.vi
cllMotorBasic1a.vi
cllMotorProj.lvproj
cllMotorProj.lvlps
cllMotorMoveClassFive1e.vi
readRootPath2.vi
cllPathname.txt
zeroSave1.vi
writeRootPath.vi
stopCallback1.vi
stepstoDeg.vi
parseStringArray.vi
numLinesInString.vi
moveAntenna1.vi
motorVisaResourceNum.vi
motorStatus2.vi
maxTurnForSeekSwitch.vi
findSwitch3b.vi
findIndex2b.vi
fileWriteZeroSave.vi
fileReadLastPostion.vi
fileLastPostion.vi
emergencyStop.vi
calcNewPos2.vi
calcIndex.vi
buttonPress.vi
motorStartup1g.vi
resetZero.vi
cllMotor2ndLevel.vi
findSwitchLev2.vi
digIOc.vi
readSwitch2ndLev.vi
readMotorSwitchFile.vi
findIndex1testcase.vi
degtoSteps.vi
switchSetup1.vi

A-2 Basic Motor VI and Functions

The basic vi that controls the motor is called cllMotorBasic. This module can be used separately if one is developing other software that needs to control the motors. The front panel of this vi is shown in Fig. A-1.

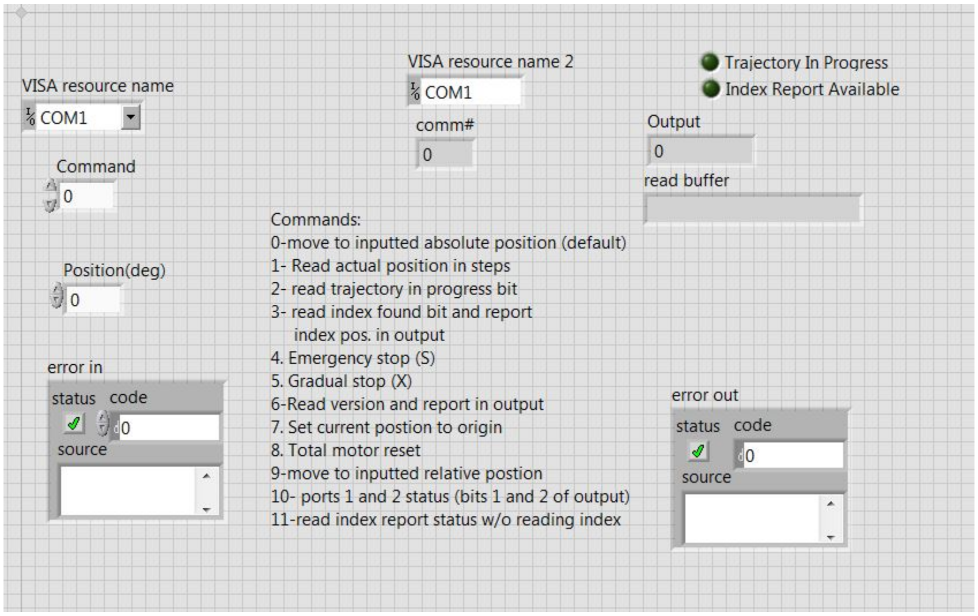

Fig. A-1 Front panel of the vi cllMotorBasic.

The commands it performs are as follows:

- 0 – Move to inputted absolute position (default)
- 1 – Read actual position in steps
- 2 – Read trajectory in progress bit
- 3 – Read index found bit and report index position in output
- 4 – Emergency stop (S)
- 5 – Gradual stop (X)
- 6 – Read version and report in output
- 7 – Set current position to origin
- 8 – Total motor reset
- 9 – Move to inputted relative position
- 10 – Ports 1 and 2 status (bits 1 and 2 of output)
- 11 – Read index report status without reading index

A-3 Other Major VI Modules

digIOc.vi communicates with the digital input/output (I/O) ports of the motor. The external switch is detected through these I/O ports.

fileWriteZeroSave.vi saves zeroing data to a file on the controller hard disk.

findIndex.vi locates the motor index and returns its value. This involves turning the motor if the index has not been detected yet. The motor index is an angle marker that is internal to the motor. It acts like a fixed position contact switch that identifies an absolute angle that is fixed within the motor. The position of the index never changes. However, the readout of the index is based on the startup angle of the motor. Upon startup, the motor must transverse past the index in order to locate it.

findSwitch3b.vi locates where the external contact switch is in relation to the current motor angle. This involves rotating the motors.

motorStartup1g.vi progresses through the zeroing routines for a motor. This involves finding the motor index and if needed the external switches.

motorStatus2.vi returns the status of the motors. This includes the firmware version and connection status.

moveAntenna1.vi turns the motors to a desired angle.

zDashboard6motorsV1b.vi runs the overall dashboard and program.

Appendix B. Location of the Software

The software is saved on the network drive of the Antennas & RF Technology Integration Branch, office symbol RDRL-SER-M, saved on L: drive under the following directory folder:

- L:\Tesny\ewcll\backup-latest labview-v14\Wall

Appendix C. Motor Specifications

C-1 Motor Description

The 6 motors are manufactured by Animatics. Motors 1 through 3 are model 2316D-PLS2 and motors 4 through 6 are model 23165D. These are the same motor physically but they have different firmware versions. The 2316Ds have the Series 4 firmware, while the 23165Ds have the newer Class 5 firmware. The software was painstakingly written to detect which versions of firmware the motors have and apply the right command set to communicate with each version. Table C-1 lists the specifications.

Table C-1 Motor specifications

Continuous torque	in-lb	2.5
	oz-in	40
	N-m	0.28
Peak torque	in-lb	4
	oz-in	64
	N-m	0.45
Nominal continuous power	W	181
No load speed	rpm	900
Continuous current at nominal power	A	5
Voltage constant	V/krpm	5
Winding resistance	ohm	1
Encoder resolution	Counts/rev	0
Rotor inertia	oz-in-s^2	0.00099
10-5	kg-m^2	0.699
Weight	lb	1
	kg	0.45
Shaft diameter	in	0.25
	mm	6.35
Shaft radial load	lb	7
	kg	3.18
Shaft axial thrust load	lb	3
	kg	1.36

C-2 Inertial Adjustments to the Motors

Adjustments were made to the inertial settings of the motors in order for them to have adequate settling times when seeking a position. The settings with their default values are as follows:

- KP=3,000, proportional gain

- KI=240, integral gain
- KD=10,000, derivative gain
- KA=0, acceleration feed forward
- KV=1,500, velocity feed forward

These were changed to the following:

- KP=6,000, proportional gain
- KI=500, integral gain
- KD=20,000, derivative gain
- KA=3,000, acceleration feed forward
- KV=3,000, velocity feed forward

List of Symbols, Abbreviations, and Acronyms

CL	closed loop
EWCLL	Electronic Warfare Closed Loop Laboratory
I/O	input/output
PC	personal computer
PXi	PCI Extension for Instrumentation
vi	virtual instrument

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